POLAR DIAGRAMS OF ULTRA-SHORT WAVE HORIZONTAL TRANSMITTING AERIALS*

BY S. S. BANERJEE

AND

G. C. NEOGI

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ABSTRACT Polar diagrams for various distances near horizontal transmitting aerials of different lengths have been obtained for ultra-short radio waves. A modulated valve oscillator was used for emitting waves from 3 to 8 metres in length. The field strengths were measured with the help of a calibrated ultra-short-wave receiver of the super regenerative type. The observed values of field strengths were compared with those deduced mathematically calculated on the theory of "induced e m.f." It has been noticed that aerials of different lengths radiate the energy along different channels and the polar diagrams for a particular length of the aerial depend on the distance at which the field strengths are measured.

INTRODUCTION

The importance of radio communication with short waves below hundred metres has been realized sufficiently long time back due to the numerous advantages which these waves possess. Recently, however, the necessity has been felt of going down to still shorter lengths of the waves specially for television, aircraft communications and upper-air weather observations. These waves which are below ten metres in length are known as ultra-short waves, and their applications are still in the early stages of development. Hence the study of these waves has been felt imperative and it has opened a great opportunity for further investigations. The application of the technology of ultra-short waves, as yet largely unexplored, has been proved to be most essential. The beacons and blind landing are well-known uses of these waves and they are also used for sending secret messages.

The guiding factor in designing a broadcast transmitter is that it should be able to produce good quality signals within a certain stipulated area around the transmitter. A definite knowledge of the field strength, near the transmitter, is therefore essential. The broadcast engineer tries to design the transmitter, so that most of the radiated energy is directed along the ground, in order to secure the largest possible service area.

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It is evident that the field strength will not only depend upon the power of the transmitter but will also depend upon the radiating system. Therefore it is necessary that the aerial must be carefully designed; and, in the case of ultra-short waves, special types of aerial have to be used due to their short lengths. On account of the limited range of the transmitter, one should be very careful that the waves may be travelling in the right direction. The directivity depends only upon the type of the aerial we use, and many investigators from time to time have tried to develop such directive aerials, and studied their polar diagrams, mostly with vertical aerials.

Though various investigations have been made in this direction, it appears that the study of single wire as directive aerial has not received adequate attention. In this communication, polar diagrams for ultra-short wave horizontal transmitting aerials of different lengths for various distances have been investigated. In order to draw the polar diagram the intensities of radiated field strengths were determined by an ultra-short wave calibrated receiver of super-regenerative type. For the purpose of radiation a modulated oscillator generating waves from 3 to 8 metres in length was employed in conjunction with horizontal aerials of different lengths varying from quarter wave to one wave in length. The plots for variation of field for different distances have been shown. Experimental polar diagrams for different wave-lengths have been drawn and verified by those obtained by calculation. Derivations of the necessary mathematical equations involved for calculating the field strength for multiples of quarter wave long aerial have been shown by the method of "induced e.m.f."

THEORETICAL

The method of calculating the field strengths for various lengths of aerial has been shown below.

If we take an aerial three-fourths of a wave long, a current antinode will be formed at the input end. The equation giving the current at any point in the aerial is represented by

$$i = \mathrm{I}e^{j\omega t} \cos my \qquad \ldots \quad (1)$$

where $m = 2\pi/\lambda$ and y = distance along the aerial from the input end (O) in Fig. 1.

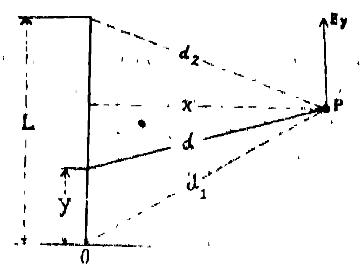

FIG.

Now the retarded scalar and vector potentials ψ and A may be denoted by

$$\psi=\int_0^l \frac{[\sigma]}{d} dy \qquad \ldots \quad (2)$$

and

$$A=\frac{K}{c}\int_0^l \frac{[i]}{d} dy \qquad \ldots \quad (3)$$

where $[\sigma]$ and $[\psi]$ denote the retarded instantaneous charge and current respectively ; K the unit vector in the direction parallel to the aerial, and c the velocity of light.

The relation between σ and i is given by

$$\frac{d\sigma}{dt}=-\frac{di}{dy}.$$

From equation (1) along with the above relation, we get

$$\sigma=\frac{I}{jc} e^{j\omega t} \sin my. \qquad \ldots \quad (4)$$

Thus from equations (1), (2), (3) and (4), we have

$$\psi=\frac{I}{jc}\int_0^l \frac{e^{-jmd}}{d} \sin my \qquad \ldots \quad (5)$$

and

$$A=\frac{I}{c} e^{j\omega t}\int_0^l \frac{e^{-jmd}}{d} \cos my\, dy. \qquad \ldots \quad (6)$$

The potential parallel to the aerial is given by

$$E_y=-\mathrm{Grad}_y \psi-\frac{I}{c}\frac{dA}{dt}$$

$$=\frac{I}{jc} e^{j\omega t}\int_0^l \frac{e^{-jmd}}{d} \cos my\, dy-\frac{jI\omega}{c^2} e^{j\omega t}\int_0^l \frac{e^{-jmd}}{d} \cos my\, dy. \qquad (7)$$

Substituting $l=3\lambda/4$ in equation (7) we get

$$E_y=\frac{2I}{jc} e^{j\omega t}\left[\frac{e^{-jmd_2}}{d_2}\right] \qquad \ldots \quad (8)$$

Now, separating real and imaginary parts, we have

$$E_y=-60\, I\frac{\mathrm{Sin}\; m\sqrt{l^2+d_1^2-2ld_1\cos\theta}}{\sqrt{l^2+d_1^2-2ld_1\cos\theta}}. \qquad \ldots \quad (9)$$

If the aerial is quarter wave long, a current node is formed at the input end. Therefore the current at any point Y (Fig. 1) along the wire is given by the relation

$$i=Ie^{j\omega t} \sin my. \qquad \ldots \quad (10)$$

Proceeding as above, it can be shown that

$$E_y = 2j\frac{I}{c}e^{j\omega t}\left[\frac{e^{-jmd_1}}{d_1} - \frac{e^{-jmd_2}}{d_2}\cos ml\right]. \qquad \ldots \quad (11)$$

Substituting $l=\lambda/4$ in equation (11) and taking real part only, we have

$$E_y = 60\, I\frac{\text{Sin } md_1}{d_1}. \qquad \ldots \quad (12)$$

The equations to calculate the field in the vicinity of half wave and one wave long aerials can be obtained from equation (11) by substituting the proper values of the lengths of the aerials. Thus it may be shown that the potential for half wave aerial will be given by

$$E_y = -30\, I\left\{\frac{\text{Sin } md_1}{d_1} + \frac{\text{Sin } m\sqrt{l^2+d_1^2-2ld_1\cos\theta}}{\sqrt{l^2+d_1^2-2ld_1\cos\theta}}\right\}. \qquad \ldots \quad (13)$$

Similarly the potential near full wave aerial will be given by

$$E_y = 30\, I\left\{\frac{\text{Sin } md_1}{d_1} - \frac{\text{Sin } m\sqrt{l^2+d_1^2-2ld_1\cos\theta}}{\sqrt{l^2+d_1^2-2ld_1\cos\theta}}\right\}. \qquad \ldots \quad (14)$$

It should be mentioned that the above relations shown in equations (13) and (14) for half wave and full wave aerials respectively have also been deduced by Carter.[6]

The polar diagrams for all the above lengths of aerial have been drawn for different distances from the aerial. Four typical diagrams have been shown below with an associated table showing the variation of field strength with angular direction in each case.

Table I shows the variation of field strength for an aerial $3\lambda/4$ long calculated from equation (9), for different angular directions at a distance of one wavelength from the input end. The corresponding polar diagram is shown in Fig. 2.

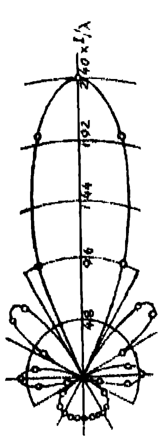

FIG. 2
Polar diagram of an aerial $3\lambda/4$ long

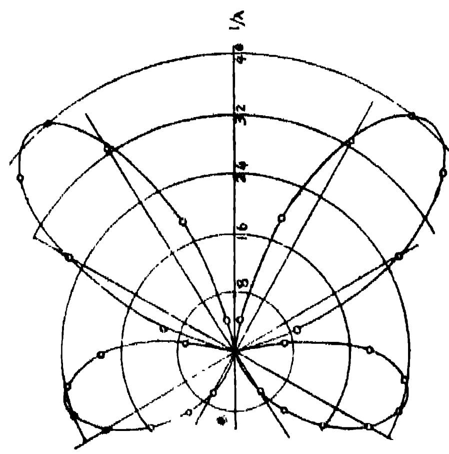

FIG. 3
Polar diagram of half wave aerial

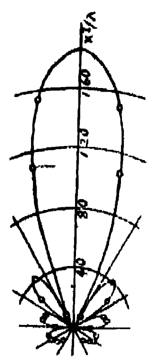

FIG. 4
Polar diagram of full wave aerial

Similar variations of field strength for half wave and full wave aerials are shown in Tables II and III respectively, while their polar diagrams are shown in Figs. 3 and 4.

TABLE I

Angular direction in degrees	Field strength in volts/metre × 1/λ	Angular direction in degrees	Field strength in volts/metre × 1/λ
0	−240.0	100	−36.0
10	−198.4	110	−14.8
20	− 97.1	120	5.1
30	9.7	130	21.3
40	73.0	140	29.0
50	76.7	150	33.1
60	38.6	160	34.4
70	− 9.0	170	34.3
80	− 40.8	180	34.3
90	− 48.0		

TABLE II

Angular direction in degrees	Field strength in volts/metre × 1/λ	Angular direction in degrees	Field strength in volts/metre × 1/λ
0	0	100	−23.6
10	5.4	110	−23.6
20	18.6	120	−20.3
30	33.0	130	−15.4
40	40.6	140	−10.2
50	41.0	150	− 5.7
60	25.6	160	− 2.5
70	9.2	170	− 1.6
80	0.6	180	0
90	− 18.2		

TABLE III

Angular direction in degrees	Field strength in volts/metre × 1/λ	Angular direction in degrees	Field strength in volts/metre × 1/λ
0	−186.0	100	3.9
10	−153.1	110	17.6
20	− 70.4	120	17.2
30	6.4	130	15.3
40	40.1	140	11.0
50	29.3	150	6.4
60	0	160	2.8
70	− 20.9	170	0.7
80	− 22.7	180	0
90	− 10.9		

It will be observed that the field strength will not show any change for different angular directions for a quarter-wave aerial at a fixed distance. The variation of field strength is, therefore, shown in Table IV as the distance from the input end is altered. The positions of maximum field strengths in the present case and the nature of the curve are shown in Fig. 5.

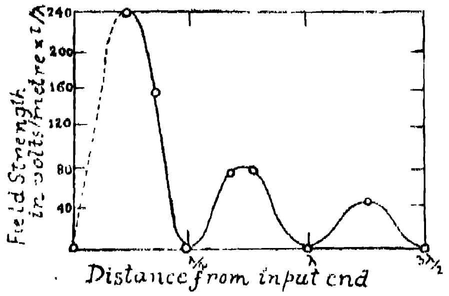

FIG. 5

Positions of maximum field strength

TABLE IV

Distance from input end	Field strength in volts/metre × 1/λ	Distance from input end	Field strength in volts/metre × 1/λ
λ/4	240	3λ/4	80
λ/3	156	λ	0
λ/2	0	5λ/4	48
2λ/3	78	3λ/2	0

EXPERIMENTAL

A modulated oscillator of the Hartley type was used for generating the ultra-short waves. A constant modulation was effected by a leak and a condenser. A super-regenerative receiver was built for measuring the field strengths. A milliammeter was put in the anode circuit of the detector stage for observing the change in its deflection due to the incoming signal. The receiver was calibrated by the same method as described by Banerjee and Parmanand,[7] in a previous paper published in this journal.

The ultra-short wave generator was connected with a horizontal aerial which was placed in a fixed direction and the receiver was moved along the circumference of a circle with the input end of the transmitting aerial as centre. The field strengths were measured at different angular directions with respect to the orientation of transmitting aerial. Special precautions have been taken, as far as possible, to avoid the reflection of the waves from the neighbouring walls of the laboratory. Most of the observations have been taken in clear open space on the terrace of the building, the reflection coefficient of which was actually found to be very small. This was evident from the absence of the formation of any interference pattern due to the direct and reflected rays. This pattern could always be found when such experiments were performed on the ground.

The wave-lengths used were between 3 to 7 metres and the lengths of the aerials were λ, $3\lambda/4$, $\lambda/2$ and $\lambda/4$.

The observed values of field strengths in the neighbourhood of a horizontal transmitting aerial, $\lambda/2$ long, at a distance of λ from the input end, and for different angular directions, are shown in Table V below. The polar diagram for the same is depicted in Fig. 6.

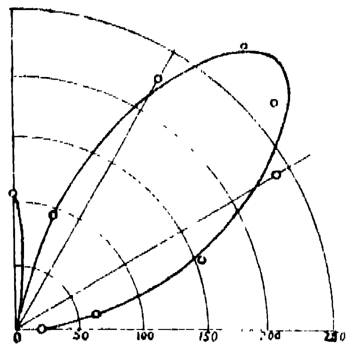

FIG. 6
Polar diagram of half-wave horizontal transmitting aerial

TABLE V

Angular distance in degrees	Field strength in milli-volts/metre	Angular distance in degrees	Field strength in milli-volts/metre
0	23	50	287
10	69	60	230
20	161	70	92
30	241	80	11.5
40	276	90	115

SUMMARY AND CONCLUSION

Field strengths have been measured at short distances in all directions from horizontal transmitting aerials of different lengths. Polar diagrams for the aerials have then been shown. In order to verify the results obtained experimentally, new equations have been derived based on the theory of "induced e.m.f." for each length of the aerial. Field strengths have been calculated from these equations, and theoretical polar diagrams have also been drawn. A modulated oscillator was used to energise the transmitting aerial and a calibrated super-regenerative receiver was employed for the purpose of measurements of the field.

It may be mentioned here that the equations derived in the present investigations could be applied for computing the fields, radiated from quarter-wave transmitting aerials and their odd multiples in addition to half-wave aerials and their multiples as generally used. It has been observed that the polar diagrams for such horizontal aerial will depend mainly on the length of the aerial and on the distances from the input end at which the field strengths are measured.

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WIRELESS SECTION,
PHYSICS DEPARTMENT,
BENARES HINDU UNIVERSITY.

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